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POWER CONVERTING METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to a method and apparatus for converting DC power to DC power of a different voltage from that of the original one.

Fig. 7 shows a first prior art voltage-drop type DC-DC converter 70. The DC-DC converter 70 converts an input voltage V_I of a DC power supply 71 to an output voltage V_O that is lower than the input voltage V_I. When a transistor TR is ON, a voltage $V_I - V_O$ is applied to a coil CL. The amount of change in current, ΔIL, when the transistor TR is turned on is expressed by $\Delta IL = \{(V_I - V_O)/L\}T_{on}$ where L is the inductance of the coil CL and T_{on} is the ON duration of the transistor TR. When the transistor TR is turned off, a commutation diode D keeps the current flowing across the coil CL. When the transistor TR is turned off, the amount of current change ΔIL is expressed by $\Delta IL = (V_O/L)T_{off}$ where T_{off} is the OFF duration of the transistor TR. When the current continuously flows across the coil CL, both current changes are equal to each other in a steady state. Therefore, the output voltage V_O is $\{T_{on}/(T_{on} + T_{off})\}V_I$, which is smaller than the input voltage V_I.

Other known types of DC-DC converters than the voltage-drop type DC-DC converter 70 include a booster type DC-DC converter and a booster/voltage-drop type DC-DC converter.

Recently, hybrid motor vehicles have been put to use in order to improve fuel efficiency and reduce the exhaust gas of motor vehicles. Hybrid vehicles use a running motor

when they are started or when they run at a low speed, and use an engine when they run at a middle speed. The operational voltage for various kinds of units, such as a headlight, which a hybrid motor vehicle is equipped, is lower than the operational voltage for the running motor. The conventional hybrid motor vehicles therefore need two power supplies, a high-voltage power supply for the running motor and a low-voltage power supply for the various kinds of units.

Fig. 8 shows a prior art high-voltage and low-voltage generating apparatus 80. The apparatus 80 has an engine 51, an alternator 52, a high-voltage battery 53, a low-voltage battery 56 and a DC-DC converter 54. The alternator 52 has a three-phase AC generator 52a and a three-phase full-wave rectifier 52b which are driven by the engine 51. A high-voltage unit (motor) 55 is connected to the high-voltage battery 53. The alternator 52 generates high-voltage DC power to charge the high-voltage battery 53. The DC-DC converter 54 lowers the voltage of the high-voltage battery 53 to charge the low-voltage battery 56 and supplies the lowered voltage to a low-voltage unit 57.

Fig. 9 shows another prior art high-voltage and low-voltage supplying apparatus 90. The apparatus 90 has two alternators 52 connected to the engine 51. The two alternators 52 respectively charge the high-voltage battery 53 and the low-voltage battery 56.

The apparatus 80 in Fig. 8 needs the large-capacity DC-DC converter 54 and two batteries 53 and 56 and thus inevitably is large and heavy. The apparatus 90 in Fig. 9 is heavy and bulky because of the two alternators 52. The apparatuses 80 and 90 in Figs. 8 and 9 are therefore unfit

for hybrid motor vehicles.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a compact power converting apparatus, which stably generates at least two DC voltages, a power generating method, and a vehicle having the power converting apparatus.

To achieve the above object, the first aspect of the present invention provides a method of supplying power using a main DC power supply for generating a predetermined voltage to supply a first output voltage substantially equal to the predetermined voltage and a second output voltage lower than the predetermined voltage. The method includes connecting a first DC power supply for generating the same voltage as the second output voltage in series to a second DC power supply for generating a differential voltage between the first output voltage and the voltage from the first DC power supply, thereby forming the main DC power supply, connecting a DC-DC converter to the second DC power supply, and stepping down the voltage output from the second DC power supply to produce the second output voltage by using the DC-DC converter.

The second aspect of the present invention provides a power converting apparatus for generating a first output voltage and a second output voltage lower than the first output voltage. The apparatus includes a first DC power supply for generating the same voltage as the second output voltage, a second DC power supply, which is connected in series to the first DC power supply for generating a voltage corresponding to a difference between the first output voltage and the voltage from the first DC power

supply, and a DC-DC converter, which is connected to the second DC power supply for converting the voltage from the second DC power supply to the second output voltage.

The third aspect of the present invention provides a method of generating a boosted voltage higher than a voltage of a main DC power supply. The method includes producing a differential voltage between a target boosted voltage and the voltage of the main DC power supply using a DC-DC converter, and producing the boosted voltage by adding the differential voltage to the voltage of the main DC power supply.

The fourth aspect of the present invention provides a power converting apparatus for generating a predetermined boosted voltage. The power converting apparatus includes a DC power supply, and a DC-DC converter, which is connected to the DC power supply, for producing a differential voltage between the predetermined boosted voltage and a voltage of the DC power supply. The predetermined boosted voltage is provided as a sum of the voltage of the DC power supply and the differential voltage.

The fifth aspect of the present invention provides a power converting method of supplying a first output voltage substantially equal to a voltage of a main battery and a second output voltage lower than the voltage of the main battery. The method includes forming the main battery by connecting a first battery for generating the same voltage as the second output voltage in series to a second battery for generating a voltage corresponding to a difference between the first output voltage and the voltage of the first battery, producing the first output voltage by adding the voltages of the first and second batteries, connecting

a charge power supply for generating a voltage lower than the voltage of the main battery to an output of a DC-DC converter, producing a differential voltage between the voltage of the main battery and the voltage of the charge power supply using the DC-DC converter, and charging the main battery with a sum of the differential voltage and the voltage of the charge power supply.

The sixth aspect of the present invention provides a power converting apparatus for generating a first DC voltage and a second DC voltage lower than the first DC voltage. The apparatus includes a first battery for generating the same voltage as the second DC voltage, a second battery, which is connected in series to the first battery for generating a differential voltage between the first DC voltage and the voltage of the first battery, and a polarity-inverting type DC-DC converter having an input connected to the second battery and an output connected to the first battery. The DC-DC converter includes a first switching element and a first diode connected in parallel to each other, a second switching element connected between the output of the DC-DC converter and the first battery, and a second diode connected in parallel to the second switching element.

The seventh aspect of the present invention provides a vehicle having a running motor operable with a predetermined first operational voltage, and a subload operable with a second operational voltage lower than the first operational voltage. The running motor is connected to a main battery assembly for generating the first operational voltage. The battery assembly includes a first battery cell for generating the second operational voltage and a second battery cell, connected in series to the first

battery cell, for generating a differential voltage between the first operational voltage and the second operational voltage. The vehicle includes a power converting apparatus, which is connected between the second battery cell and the subload, for converting the voltage of the second battery cell to the second operational voltage and supplying the second operational voltage to the subload.

Other aspects and advantages of the present invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention that are believed to be novel are set forth with particularity in the appended claims. The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a schematic block diagram of a power converting apparatus according to a first embodiment of the present invention;

Fig. 2 is a schematic block diagram of the power converting apparatus in Fig. 1, showing the flows of currents when a transistor is off;

Fig. 3 is an waveform diagram showing a pulse signal for driving the transistor;

Fig. 4 is a schematic block diagram of a power converting apparatus according to a second embodiment of the present invention;

Fig. 5 is a schematic block diagram of the power

converting apparatus in Fig. 4, which is being charged;

Fig. 6 is a schematic block diagram of a power converting apparatus according to a third embodiment of the present invention;

Fig. 7 is a first prior art circuit diagram of a voltage-drop type DC-DC converter;

Fig. 8 is a schematic block diagram of a prior art double power-supply system for a vehicle; and

Fig. 9 is a schematic block diagram of another prior art double power-supply system for a vehicle.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

A power converting apparatus 100 according to a first embodiment of the present invention will now be described referring to Figs. 1 to 3.

As shown in Fig. 1, the power converting apparatus 100 includes a battery assembly 1 and a DC-DC converter 5.

The battery assembly 1, which is a DC power supply for a vehicular driving motor, has a first battery cell 1a and a second battery cell 1b connected in series. The first battery cell 1a generates a voltage that is the same as a desired low-voltage DC output. The second battery cell 1b generates a differential voltage between the high-voltage DC output and the output voltage of the first battery cell 1a. The voltage of the desired low-voltage DC output is substantially equal to the operational voltage (12V) for low-voltage units (e.g., a headlight 6) of a vehicle. The voltage of the high-voltage DC output is substantially equal to the operational voltage (36V) for

high-voltage units (e.g., a running motor 4). The battery assembly 1 has a 36-V output terminal 1d and a 12-V intermediate terminal or tap 1c. The charge voltage of the battery assembly 1 is 36V and the charge voltage at the intermediate tap 1c is 12V.

An alternator 3 includes a generator 3a and a full-wave rectifier 3b that are driven by an engine 2. While the engine 2 is running, the alternator 3 charges the battery assembly 1 with a voltage of 36V. The running motor 4 is connected to the battery assembly 1.

The DC-DC converter 5, which is a polarity-inverting type or buck boost type, is connected to the battery assembly 1. The headlight 6 is connected to the battery assembly 1 via the DC-DC converter 5. The running motor 4 is connected between the battery assembly 1 and the DC-DC converter 5.

The DC-DC converter 5 has a switching element or transistor TR1, an inductor L1, a fly-wheel diode D1, a current sensor CS1, a control circuit 7 and capacitors C1 and C2. The transistor TR1 is preferably MOSFET (Metal Oxide Semiconductor Field Effect Transistor). The transistor TR1 is connected in series to the inductor L1. That is, the transistor TR1 has a drain connected to a positive terminal 1d (36-V terminal) of the battery assembly 1 and a source connected to the inductor L1. The fly-wheel diode D1 is located between a ground terminal or 0-V terminal and a node between the transistor TR1 and the inductor L1. The capacitor C1 is located between the 36-V terminal 1d and the 12-V terminal 1c of the battery assembly 1. The capacitor C2 is located between the 12-V terminal 1c of the battery assembly 1 and the 0-V terminal.

The transistor TR1 and the current sensor CS1 are connected to the control circuit 7. Also connected to the control circuit 7 are a first voltage sensor 8 for detecting an output voltage of the running motor 4 and a second voltage sensor 9 for detecting an output voltage V_0 of the headlight 6. The control circuit 7 controls the ON/OFF switching of the transistor TR1 with a high frequency in such a way that the ratio of the detected voltage of the first voltage sensor 8 to the detected voltage of the second voltage sensor 9 becomes 3:1. This makes it possible to keep the ratio of the output voltage to the running motor 4 to the output voltage to the headlight 6 at 3:1.

The control circuit 7 incorporates a comparator 7a and a triangular wave oscillator 7b. The comparator 7a compares the difference between the detected voltages of the first and second voltage sensors 8 and 9 and the output of the triangular wave oscillator 7b and generates a transistor drive pulse signal (see Fig. 3) according to the comparison result. The control circuit 7 supplies the transistor drive pulse signal to the transistor TR1. The transistor drive pulse signal controls an ON time T_{on} and OFF time T_{off} of the transistor TR1. When the ratio of the ON time T_{on} of the transistor TR1 to the OFF time T_{off} is 1 : 2, for example, the ratio of the detected voltage of the first voltage sensor 8 to the detected voltage of the second voltage sensor 9 is 3 : 1. When the ratio of the detected voltages of the first and second voltage sensors 8 and 9 is shifted from 3 : 1, the control circuit 7 changes the ON time T_{on} and the OFF time T_{off} to correct for the deviation.

The operation of the power converting apparatus 100

will now be discussed.

The DC-DC converter 5 has input terminals that are the 36-V terminal 1d and the 12-V terminal 1c of the battery assembly 1, and 12V of the battery assembly 1 is a ground voltage in the DC-DC converter 5. Therefore, the input voltage V_I of the DC-DC converter 5 is 24V. The output voltage V_0 of the DC-DC converter 5 is -12V because the 12-V intermediate tap 1c is taken as a reference.

When the transistor TR1 is turned on, the current flows as indicated by an arrow A in Fig. 1. This causes the inductor L1 to store the power that is supplied from the second battery cell 1b. Irrespective of the switching of the transistor TR1, the capacitor C2 is charged with the current from the first battery cell 1a and the current is supplied to the headlight 6 from the capacitor C2.

When the transistor TR1 is turned off while the current is flowing in the inductor L1, the diode D1 keeps the current flowing through the inductor L1, the fly-wheel diode D1 is set on to keep this current. Then, the power stored in the inductor L1 is supplied to the headlight 6 (an arrow C in Fig. 2) as a low-voltage DC output.

Therefore, the power that drives the headlight 6 is supplied from both the DC-DC converter 5 and the first battery cell 1a. When the current supplied to the headlight 6 is 100 A, for example, a current of 67 A from the DC-DC converter 5 and a current of 33 A from the battery cell 1a are both supplied to the headlight 6.

When the power converting apparatus 100 is in a steady state, the output voltage V_0 and an output current

I_O are expressed by the following equations.

$$V_O = (T_{on}/T_{off})V_I$$

$$I_O = (V_I T_{on})^2/\{2L(T_{on} + T_{off})V_O\}$$

The control circuit 7 controls the ON time T_{on} and OFF time T_{off} in such a way as to set $V_O = -V_I/2$, so that 2/3 of the total power supplied to the headlight 6 is supplied from the DC-DC converter 5 and the remaining 1/3 is supplied from the battery assembly 1. Specifically, the control circuit 7 monitors the output current I_O detected by the current sensor CS1 and controls the ON time T_{on} and the OFF time T_{off} in such a manner that the ratio of the voltage supplied to the running motor 4 to the supply voltage V_O to the headlight 6 becomes 3 : 1.

When a current of 33 A or larger is supplied from the battery cell 1a (overloaded state), for example, the ratio of the detected voltages of the voltage sensors 8 and 9 is shifted from 3:1. In this case, after the overloaded state is released, the control circuit 7 controls the ON time T_{on} and the OFF time T_{off} in such a manner that the ratio of the detected voltages of the voltage sensors 8 and 9 becomes 3:1.

If there is no variation in the load of the headlight 6, the ratio of the ON time T_{on} to the OFF time T_{off} does not change. Because the load of the headlight 6 frequently varies, however, the control circuit 7 controls the ON time T_{on} and the OFF time T_{off} based on detection signals from the first and second voltage sensors 8 and 9 in such a way that the ratio of the detected voltages of the voltage sensors 8 and 9 becomes 3:1.

As shown in Fig. 3, the voltage of the triangular wave signal of the triangular wave oscillator 7b periodically changes. The comparator 7c generates a pulse signal whose level goes to high when a comparison voltage Vc based on the difference between the detection signals of the first and second voltage sensors 8 and 9 is smaller than the voltage of the triangular wave signal and goes to low when the comparison voltage Vc is greater than the voltage of the triangular wave signal, and sends the pulse signal to the transistor TR1. The transistor TR1 is turned on when the pulse signal has a high level, and is turned off when the pulse signal has a low level. When the comparison voltage Vc is equal to a predetermined value Vs, the ratio of the detected voltages of both voltage sensors 8 and 9 is 3:1. At this time, the control circuit 7 outputs a pulse signal whose ratio of the ON time T_{on} to the OFF time T_{off} is 1:2. When the ratio of the detected voltages of both voltage sensors 8 and 9 is larger than 3:1, the detected voltage of the first voltage sensor 8 is relatively large and the comparison voltage Vc is larger than the value Vs. At this time, the ON time T_{on} is controlled to be shorter. When the ratio of the detected voltages of both voltage sensors 8 and 9 is smaller than 3:1, the comparison voltage Vc is smaller than the value Vs. At this time, the ON time T_{on} is controlled to be longer. By adjusting the ON time T_{on} of the switching element using the triangular wave signal, the control circuit 7 controls the switching of the transistor TR1 in such a way that the ratio of one output voltage to the other coincides with a target value.

The capacitors C1 and C2 smooth the current from the battery assembly 1. When the capacitance of the transistor TR1 is relatively large, the capacitor C1 can be

eliminated.

The power converting apparatus 100 of the first embodiment has the following advantages.

The DC-DC converter 5 does not directly step down the high voltage of 36V of the battery assembly 1 to the predetermined voltage of 12V, but steps down the output voltage of 24V of the second battery cell 1b to the predetermined voltage of 12V. Since the DC-DC converter 5 needs a small capacity, the DC-DC converter 5 can be made compact, which makes the power converting apparatus 100 compact.

The battery assembly 1 has the first battery cell 1a that outputs a voltage of 12V equal to the voltage of the low-voltage DC output, the second battery cell 1b that outputs a voltage of 24V or the difference between the voltage of the high-voltage DC output and the output voltage of the first battery cell 1a, and the intermediate tap 1c. It is therefore possible to easily secure the layout space for the first and second battery cells 1a and 1b.

As the input terminal of the DC-DC converter 5 is connected to the second battery cell 1b and the output terminal to the first battery cell 1a, the power converting apparatus 100 has a simple structure.

Being compact and simple in structure, the power converting apparatus 100 is suitable for use in a vehicle.

Because a part of the output of the DC-DC converter 5 is used to charge the first battery cell 1a when the

discharge capacity of the first battery cell 1a drops down to or below a predetermined value, discharging the first battery cell 1a alone is suppressed.

Second Embodiment

A power converting apparatus 110 according to a second embodiment of this invention will now be described referring to Figs. 4 and 5. The power converting apparatus 110 steps down or boosts the supply voltage. The power converting apparatus 110 has a second transistor (MOSFET) TR2 in place of the fly-wheel diode D1 used in the first embodiment.

Each of the first and second transistors TR1 and TR2 has a parasitic diode between its source and drain as indicated by dotted lines in Fig. 4. Therefore, the use of MOSFETs for the first transistor TR1 (switching element) and the second transistor TR2 is equivalent to the use of a parallel circuit of a switching element and a diode. When the second transistor TR2 is kept off, the DC-DC converter 5 functions the same as the first embodiment.

In the power converting apparatus 110, therefore, the second transistor TR2 is normally kept off and the first transistor TR1 is switched on or off. When the output voltage of the battery assembly 1 falls below a predetermined voltage, an additional DC power supply 10 is connected to the output terminal of the DC-DC converter 5 as shown in Fig. 5 to charge the battery assembly 1. The additional DC power supply 10 can have the same output voltage as the output voltage of the first battery cell 1a.

At the time of charging the battery assembly 1, the

first transistor TR1 is kept off and the second transistor TR2 is switched on and off. In this case, the DC-DC converter 5 serves as a booster type DC-DC converter.

The output voltage of the DC power supply 10 or the input voltage to the DC-DC converter 5 in a boost mode is expressed by V_I2 and the output voltage of the DC-DC converter 5 is expressed by V_O2. The voltage that is applied to the inductor L1 when the second transistor TR2 is on is V_I2 while the voltage that is applied to the inductor L1 when the second transistor TR2 is off is $(V_O2 - V_I2)$. When the current continuously flows across the inductor L1, therefore, the amount of a change in the current flowing across the inductor L1 during the ON time T_{on} is substantially equal to the amount of a change in the current flowing across the inductor L1 during the OFF time T_{off}. This is shown in the following equation.

$$(V_I2/L)T_{on} = \{(V_O2 - V_I2)/L\}T_{off}$$

Thus, $V_O2 = \{(T_{on} + T_{off})/T_{off}\}V_I2$.

The control circuit 7 controls the ON/OFF switching of the second transistor TR2 in such a way that the ratio of V_O2 to V_I2 becomes 2:1. In other words, the control circuit 7 controls the second transistor TR2 in such a way that the ratio of the difference (24V) between the charge voltage of 36V of the battery assembly 1 and the output voltage of 12V of the DC power supply 10 to the output voltage of 12V of the DC power supply 10 is maintained at 2:1. As a result, the battery assembly 1 is charged with a voltage of 36V, which is the output voltage of 12V of the DC power supply 10 plus the boosted output voltage of 24V of the DC-DC converter 5.

The second embodiment therefore has the advantages of the first embodiment and the following additional advantages.

The DC-DC converter 5 outputs a voltage that is the output voltage (12V) of the DC power supply 10 subtracted from the charge voltage (36V) of the battery assembly 1, and this output voltage (24V) is added to the output voltage (12V) of the DC power supply 10. The battery assembly 1 can be charged with the resultant voltage (36V). This means that the battery assembly 1 can be charged using the battery installed in another vehicle which has only the conventional battery for low-voltage units.

The power converting apparatus 110 can be constructed by providing the polarity-inverting type DC-DC converter 5 with the transistor TR1, which has a switching element and a diode connected in parallel, and the transistor TR2, which also has a switching element and a diode connected in parallel and which is used in place of the fly-wheel diode D1.

The transistors (MOSFETs) TR1 and TR2 serve as diodes when they are turned off in a step-down mode or a boost mode. Therefore, the structure of the power converting apparatus 110 is simpler than that of the power converting apparatus that has a parallel circuit of a switch element and a diode.

Third Embodiment

A power converting apparatus 120 according to a third embodiment of this invention will now be described referring to Fig. 6. The power converting apparatus 120

has an insulated DC-DC converter (fly-back converter) 13 that has a transformer capability.

As shown in Fig. 6, the fly-back converter 13 is connected to the second battery cell 1b, so that the output voltage (24V) of the second battery cell 1b is applied to the fly-back converter 13. The headlight 6 is connected to the output terminal of the fly-back converter 13 and the first battery cell 1a.

When a transistor TR is on, electric energy is stored in a transformer T. When the transistor TR is off, on the other hand, the electric energy stored in the transformer T is discharged. Given that the number of turns of the primary winding of the transformer T is denoted by n1 and the number of turns of the secondary winding is denoted by n2, the following equation is satisfied when the secondary current continuously flows.

$$V_O = (n2/n1)(T_{on}/T_{off})V_I$$

The control circuit 7 controls the ON/OFF action of the transistor TR in such a way that the output voltage V_O of the fly-back converter 13 coincides with the operational voltage of 12V for the headlight 6.

The third embodiment has the following additional advantages.

The use of the insulated DC-DC converter 5 permits the power converting apparatus 120 to be used as a switching power supply that must provide electric insulation between the input side device and the output side device.

As the power converting apparatus 120 has the insulated fly-back converter 13, it has a simpler structure than one that has a forward converter.

The first to third embodiments may be modified as follows.

Instead of using the battery assembly 1 that has the first battery cell 1a and the second battery cell 1b, the first battery cell 1a and the second battery cell 1b may be arranged separately.

In the first to third embodiments, the control circuit 7 that performs analog control of the ratio of the ON time of the transistor TR1 to the OFF time thereof may be replaced with a control unit that has a CPU. In this case, the CPU computes the ratio of the ON time of the transistor TR1 to the OFF time thereof based on the detection signals of the first and second voltage sensors 8 and 9. Preferably, the ON/OFF switching of the transistor TR1 is controlled using PWM based on this computed ratio. Available as this CPU is a CPU that is used in an apparatus other than the power converting apparatus 100, 110 or 120.

The first embodiment may use current sensors which respectively detect the amount of the current flowing across the inductor L1 and the amount of the current coming back to the battery cell 1a from the headlight 6. In this case, the control circuit 7 controls the transistor TR1 in such a manner that the ratio of the value of the two currents detected by the current sensors becomes a predetermined value (e.g., 2:1). In the second and third embodiments, the currents may be detected instead of the voltages. In this case too, the control circuit 7 controls

the transistor based on the detected current values.

In the second embodiment, a parallel circuit of a bipolar transistor and a diode may be provided in place of the transistors (MOSFETs) TR1 and TR2.

Instead of the MOSFET and the bipolar transistor, for example, other switching elements, such as an SIT (Static Induction Transistor) and a thyristor, may be used.

Instead of the running motor 4, another unit may be connected to the power converting apparatus 100, 110 or 120. The power converting apparatus 100, 110 or 120 may be adapted for use in a vehicle that is not equipped with the running motor 4 or may be adapted for use in a battery-powered vehicle which does not have an engine.

The power converting apparatus 100, 110 or 120 may be adapted for use in other apparatuses and equipment than a vehicle.

The fly-back converter 13 may be replaced with another type of DC-DC converter which has the transformer T.

A booster type insulated converter whose transformer T has a different turn ratio of the primary winding to the secondary winding from that of the transformer T of the fly-back converter 13 may be used.

It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Therefore, the present examples and

embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.